TUNE AND LIFETIME STUDIES AT THE AUSTRALIAN SYNCHROTRON

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Abstract

The 3GeV Australian Synchrotron [1,2] will begin operation in March 2007. This paper outlines the tune and lifetime measurement systems. It also provides a summary of a number of studies completed using these systems. Three different tune measurement systems have been tested. Lifetime measurements made using the DCCT were used to optimise the strengths of the harmonic sextupoles and the location of the tunes. The vertical aperture was determined using scrapers. Beta-function measurements have been completed by shunting individual quadrupoles and noting the resultant tune changes. Chromaticity measurements have been made by observing the change in tune as the RF frequency is varied.

TUNE MEASUREMENT

Spectrum Analyser with Tracking Generator

A Rohde and Schwarz FSL spectrum analyser with tracking generator is the current default tune measurement method. The input to the spectrum analyser is a signal from a stripline. The tracking generator output is amplified to around 10 Watts before being fed, in series, to the horizontal then the vertical excitation kickers.

A C-program was written to allow MATLAB to quickly obtain the positions of the peaks.

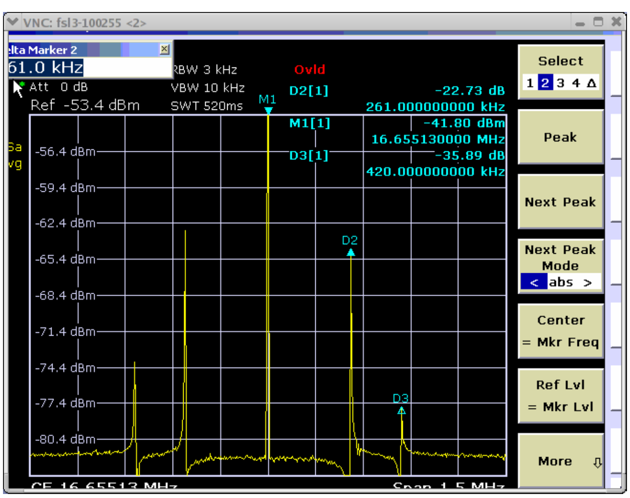

Figure 1: Tune measurement using a spectrum analyser with tracking generator.

Real-Time Spectrum Analyser in Conjunction with Arbitrary Waveform Generator

A Tektronix RSA3303A real time spectrum analyser was trialled as a tune measurement device. The stripline was used as a pickup. An Agilent 33220A arbitrary waveform generator was used to provide white noise up to 6 MHz. The signal from the noise generator was amplified and fed to the horizontal and vertical excitation kickers.

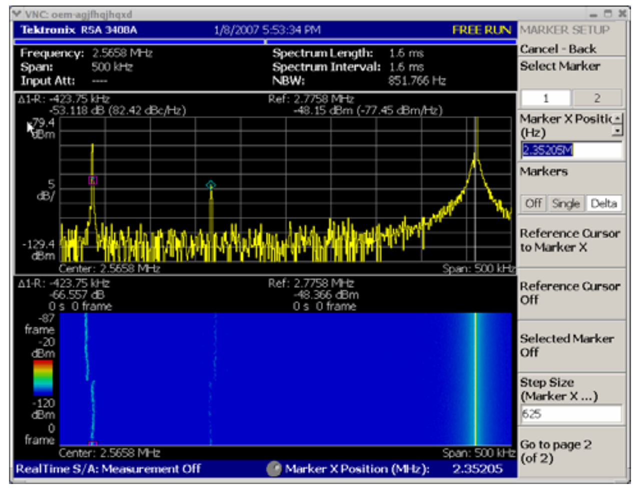

Figure 2: Tune measurement using a real time spectrum analyser and white noise generator. The waterfall plot shows a small jump in tune as a single quadrupole is shunted.

Injection Kicker with BPM Button Spectral Analysis

We have observed that our injection kickers provide a transient beam excitation in both the horizontal and vertical planes. To measure the tunes a single injection kicker is used, set to a low strength. Fourier analysis of the data from a triggered BPM button [3] reveals the tunes.

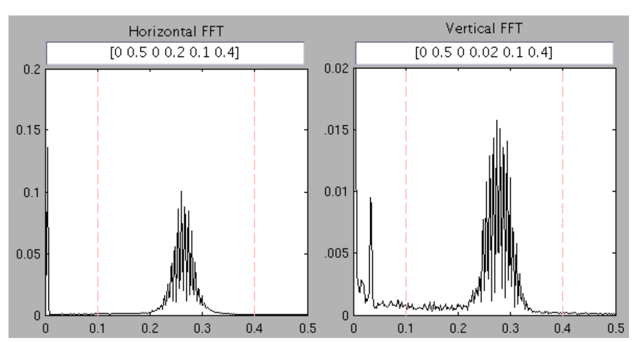

Figure 3: The tune peaks obtained by a fourier analysis of the BPM button data. Note that the large tune spread in this figure is due to the fact that the sextupoles were off.

LIFETIME MEASUREMENT

The Bergoz DCCT (Direct Current Current Transformer) provides a DC voltage proportional to the storage ring current. This is then fed to an ADC through an RC filter. The data is provided to MATLAB where the lifetime is determined using a gradient fit.

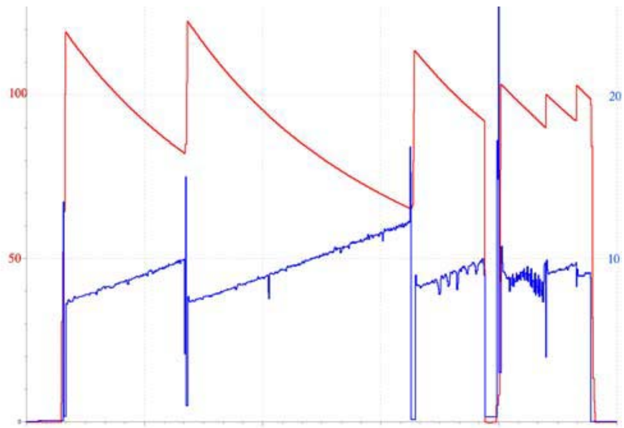

Figure 4: An example of a current (red) and lifetime (blue) measurements taken over 16 hours during commissioning activities.

A single tune or sextupole scan may require hundreds of lifetime measurements. Therefore, it is important that each lifetime measurement is completed as quickly as possible. To achieve this, it was important that the noise on the DCCT was reduced to the minimum achievable level.

STUDIES USING TUNE AND LIFETIME MEASUREMENTS

Harmonic Sextupole Optimisation

The lifetime was plotted as a function of the harmonic sextupole strength. It was found that the lifetime was maximised when the SDA family was set 15% higher than the SFA family.

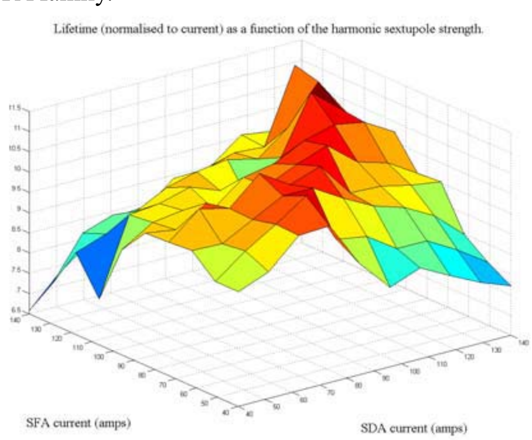

Figure 5: The change in beam lifetime as the harmonic sextupole families were varied.

Tune Space Optimisation

A tune scan was completed. With a ring symmetry of 14, the tune had very little effect on the lifetime. In order to see an effect, a single quadrupole was shunted to create a ring symmetry of 1. Figure 6 below shows that there was a clear effect on the lifetime as the tunes approached lines of resonance. This plot will become useful as wigglers are installed and the symmetry of the ring is affected.

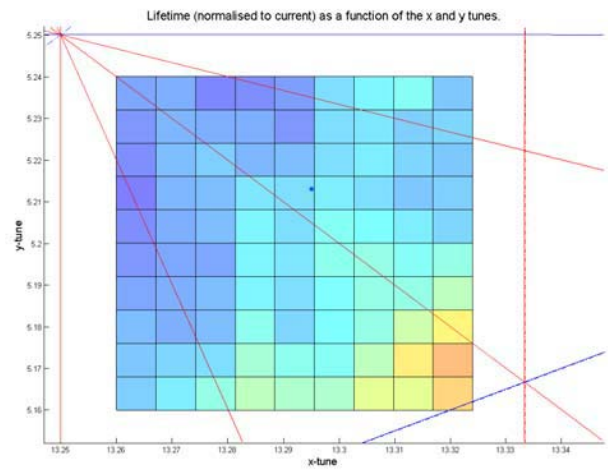

Figure 6: The change in beam lifetime as the horizontal and vertical tunes were varied (dispersion was kept constant).

Measurement of Vertical Aperture

The vertical aperture was measured at the position of the scrapers. Each scraper was moved in and the lifetime plotted versus scraper position. It was found that the scrapers are offset by 150 μm. In the plot below (figure 7) this offset has been removed.

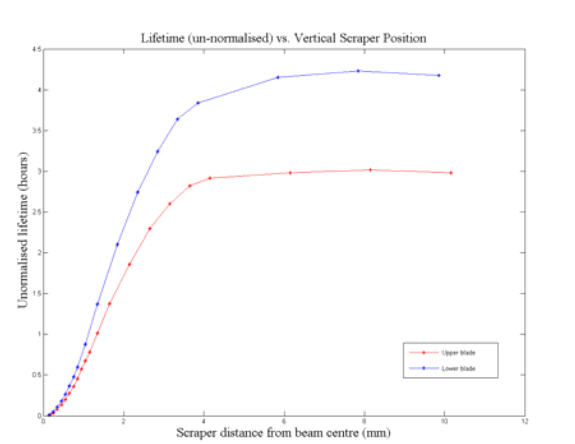

Figure 7: The lifetime as a function of the position of upper and lower vertical scrapers. Note that each data set was taken at different beam currents.

Beta function measurement

Beta functions are measured in two ways. Direct measurements are made by shunting individual quadrupole magnets and observing the change in the tune. The vertical beta function at a given QD is equal to

$$\beta_y = \frac{4\pi \cdot \Delta \nu_y}{\Delta k_l},$$

where β_y is the vertical beta function at the quadrupole, and $\Delta \nu_y$ is the change in tune resulting from the change in the quadrupole's integrated field strength, Δk_l.

The beta functions can also be calculated from a calibrated model. A calibrated model is a model which has been adjusted so that its behaviour resembles that of the real machine. Such a model can be created using the Linear Optics Closed Orbits (LOCO) [4] method. In this case the quadrupole strengths in the model are adjusted so that the model's orbit response matrix more closely resembles that of the real machine.

The calibrated model's vertical beta function is plotted with the experimentally determined vertical beta function at the QD magnets (figure 8). It can be seen that the two methods are in close agreement.

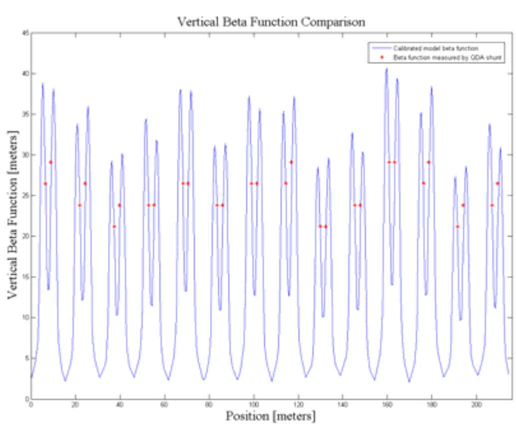

Figure 8: Comparison of calibrated model beta-functions with the experimentally determined beta-functions at the position of the QDs. Note that this data was taken in the early stages of commissioning before any adjustments were made to the optics.

Chromaticity Measurement

Chromaticity measurements are made by plotting the change in tune as a function of the momentum shift. The data is fitted with a second order polynomial. The coefficient of the linear term can be taken to be the chromaticity.

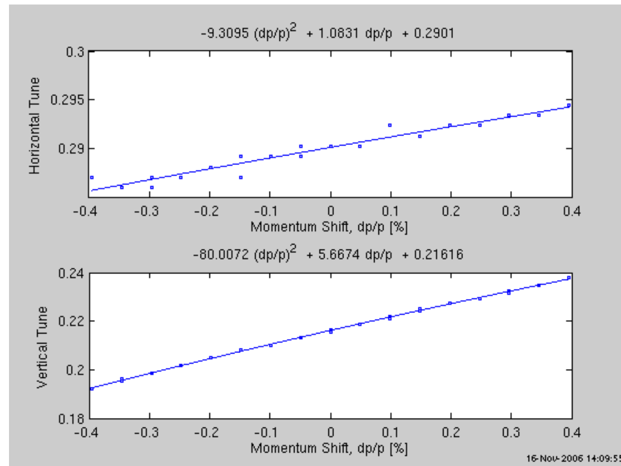

Figure 9: Tune versus momentum shift. In this case the chromaticity was measured as: $\xi_x = 1.08$ and $\xi_y = 5.67$.

REFERENCES

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[4] J. Safranek*, G. Portmann, A. Terebilo, SSRL/SLAC, Stanford, C. Steier, LBNL, Berkeley, "MATLAB-Based LOCO", EPAC'02, p. 1184.